

3.16 RESULTS FOR THERMAL NOISE

Thermal noise power is modeled by a constant value in *RADGUNS*. Thermal noise is related to receiver noise figure and bandwidth by:

$$P_N = kT_0 F_N B$$

where:

P_N	=	Thermal noise power (W)
k	=	Boltzmann's constant = 1.38×10^{-23} J/deg
T_0	=	Standard temperature = 290 K
F_N	=	Noise figure
B	=	Receiver bandwidth (Hz).

Thermal noise power and bandwidth values used in *RADGUNS*, as well as the calculated noise figure were compared to the values shown in Reference 7. These values were also compared to average values obtained from system calibration tests. Results for this assessment are shown in Table 3.16-1.

TABLE 3.16-1. Thermal Noise Assessment Results.

Data Source	Major Conditions	Statistical MOEs	Results
Reference 7	S&TI - Conditions unknown	Comparison of BW and F_N values	Matches nominal values
Range Test	Instrumented electrical and RF measurements from several systems over a six year period	Comparison of modeled P_N to value obtained with mean of measured BW and F_N values	v.1.9 BW and F_N values are 16.2% and 23.3% higher than measured means; P_N value is 35.7% higher

3.16.1 Assessment – Case 1

Assessment of the thermal noise functional element in *RADGUNS* v.1.8 revealed that the thermal noise value used in the model was 38.4% greater than that derived from range test measured mean bandwidth and noise figure values. A Model Deficiency Report was submitted documenting this result. However, because the range test documentation is poor, a decision was made that the model should reflect the most current intelligence information available. Consequently, in *RADGUNS* v.1.9, the thermal noise value was adjusted to match the value obtained with the nominal noise figure and bandwidth values listed in Reference 7.

Test Data Description. Forty-four radar receiver bandwidth and 72 noise figure measurements were obtained from several systems over a period of six years. Some of these measurements are tagged with comments such as “questionable,” and the range of values is great (bandwidth varies $\pm 48\%$ from the mean and noise figure varies $\pm 21\%$). Reference 7, the most current exploitation report available on the system, contains nominal noise figure and bandwidth values with a range about each. According to range personnel, some of the measurements obtained in the above mentioned range tests were incorporated into the values documented in Reference 7.

Validation Methodology. *RADGUNS* v.1.9 uses a constant thermal noise value which is the product of Boltzmann's constant, IEEE standard temperature, radar receiver bandwidth, and a receiver noise figure value. Thermal noise power was calculated from the minimum, nominal, and maximum values given for receiver noise figure and bandwidth in Reference 7 and from the means computed from the range test measurements. These values were compared to the value in *RADGUNS*. To assess the effect of thermal noise on detection and tracking performance, the thermal noise value in the model was changed to each of the calculated values.

Results

Table 3.16-2 shows the percentage difference between model values for bandwidth, noise figure, and thermal noise power and those shown in Reference 7 and obtained through range test. The thermal noise power in the model was calculated from the nominal noise figure and bandwidth values shown in Reference 5; therefore, the percentage difference between *RADGUNS* and the nominal value in the reference is listed in Table 3.16-2 as zero.

TABLE 3.16-2. Percent Difference Between Modeled Values and Reference 5 and Range Test Values.

	Reference 5 lower limits	Range Test means	<i>RADGUNS</i> / Reference 5 nominal	Reference 5 upper limits
Bandwidth (MHz)	-23.5	-16.2	0	23.5
Noise Figure ($\times 10^{-12}$)	-36.9	-23.3	0	58.5
Thermal Noise (pW)	-51.7	-35.7	0	95.8

Tables 3.16-3 and 3.16-4 demonstrate the effect of each of the upper and lower computed thermal noise values on detection and tracking of a 0 dBsm and a m target flying a linear flight path at 200 m/s. An engagement between the system of interest and a medium sized fighter flying along a linear flight path at 200 m/s was simulated.

TABLE 3.16-3. Effect of Thermal Noise on Detection and Tracking of a 0 dBsm Target.

	Reference 5 lower limits	<i>RADGUNS</i> / Reference 5 nominal	Reference 5 upper limits
Detection range (m)	10853.4	9175.8	7958.2
Average Tracking Error			
Azimuth (mrad)	1.00	1.11	1.24
Elevation (mrad)	0.45	0.45	0.44
Range (m)	0.64	0.61	0.59

TABLE 3.16-4. Effect of Thermal Noise on Detection and Tracking of a
–10 dBsm Target

	Reference 5 lower limits	<i>RADGUNS</i> / Reference 5 nominal	Reference 5 upper limits
Detection range (m)	6323.0	5287.5	4393.1
Average Tracking Error			
Azimuth (mrad)	1.51	1.68	1.90
Elevation (mrad)	0.45	0.47	0.51
Range (m)	0.67	0.62	0.55

The effect of thermal noise on detection range increases as target RCS increases. This effect is shown for four target RCSs in Figure 3.16-1. Although the effect of thermal noise variations on large targets is significant, it is important to note that large targets are detected well outside the tactical range of the system. Thermal noise variations have very little effect on tracking performance.

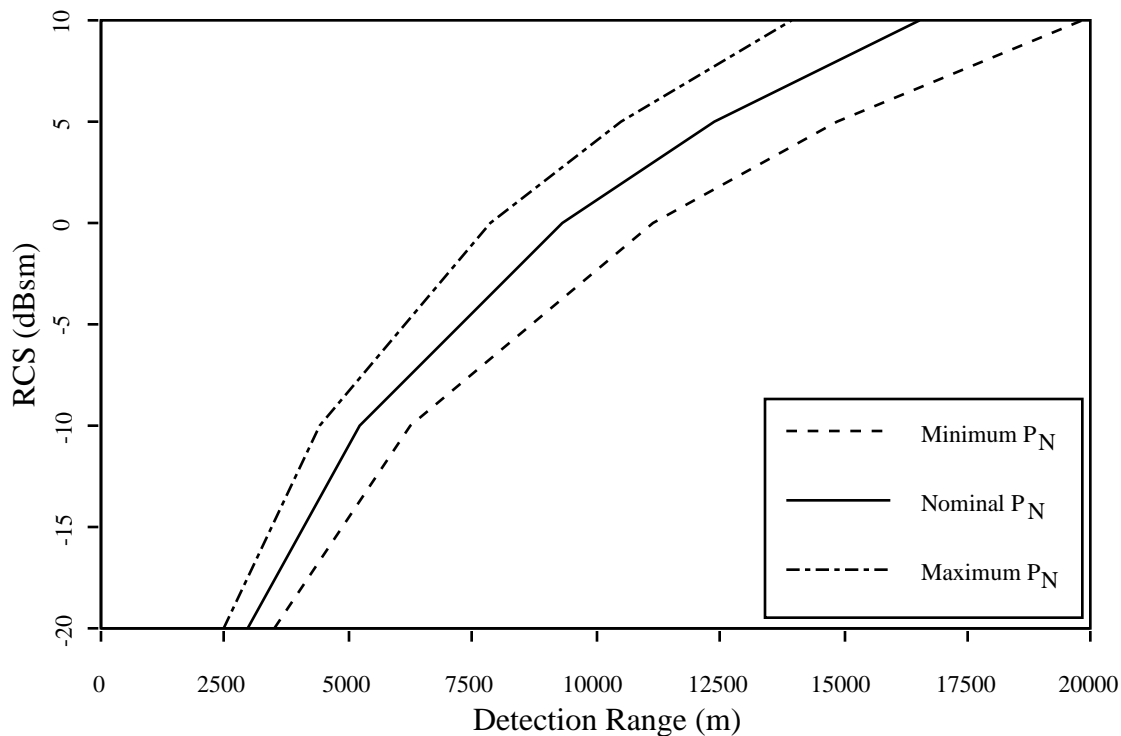


FIGURE 3.16-1. Effect of Thermal Noise on Detection Range
for Varying Target RCS.

Conclusions

The thermal noise value in v.1.9 matches the value derived from the nominal bandwidth and noise figure values published in Reference 7. This value is randomly varied within $\pm 20\%$ of nominal between repetitions of a particular engagement when a Monte Carlo

simulation is executed. The reference indicates that receiver bandwidth may vary $\pm 23.5\%$ of nominal, and the noise figure may be 36.9% lower and 58.5% higher than nominal, resulting in a thermal noise value 51.7% lower and 95.8% higher than nominal in the extreme case where both bandwidth and noise figure values are at either their lower or upper limits. Variations in thermal noise power have a significant effect on detection range for large targets. However, because large targets are detected well outside the tactical range of the system, shooting performance will not be significantly affected. Thermal noise variations have less of an impact on the detection range of low observable targets; however, because these detections may occur at or near the tactical range of the system, the effect of thermal noise on shooting performance in these cases may be great.